S/No. 10/054,826

REMARKS

This amendment is responsive to the Official Action dated June 15, 2004. Claims 1-28 were pending in the application.

No claims were allowed.

No changes have been made to the claims. Accordingly, claims 1-28 are currently pending.

Petition for Extension of Time:

A petition for an extension of the response time from September 15, 2004 to October 15, 2004 is attached.

Claim Rejections under 35 USC § 103:

Claims 1-28 were rejected under 35 USC § 103 as being obvious over U.S. Patent No. 5,719,894, issued to Jewell ("the '894 patent"), in view of the U.S. Patent 6,584,130, issued to Hanke ("the '130 patent"). In the subsequent discussion, we will show that, in fact, the '894 patent addresses completely different issues in the design of Vertical-Cavity Surface-Emitting Lasers (VCSELs) than our application, and so does not relate to the points of our application. Furthermore, The '130 patent pertains to the design of "Edge Emitting Lasers," in which many design issues are significantly different, so that the invention in the '130 patent would not solve the problem addressed in our application and is thus a non-analogous art.

Accordingly, Applicant respectfully disagrees and requests reconsideration.

The '894 patent, in most part, and our application, in its entirety, relate to

Vertical-Cavity Surface-Emitting Lasers ("VCSELs"). Both address the crucial interaction in VCSELs between the cavity emission peak and the active region's gain peak, but for completely different reasons.

The VCSEL emission wavelength is solely determined by the thickness of its resonant cavity, namely the region between the top and bottom mirrors. The two mirrors are made highly reflective, to create a very high Q resonant cavity, one in which light bounces back and forth between the mirrors hundreds of times before leaving the cavity. This forces the bouncing photons to pass through the very thin active region in the cavity hundreds of times, increasing their chances of stimulating radiative transitions in the very thin active region. For a high Q cavity, the cavity emission peak is very narrow, that is, the range of wavelengths of the photons that can bounce back and forth between the mirrors hundreds of times is very narrow and is commonly called "the cavity peak." In order for the bouncing photons to have a chance of stimulating emission in the active region to induce lasing, that active region must have transition energies, whose corresponding stimulated photon wavelengths match the cavity peak. The range of the transition energies, and of the corresponding photon wavelengths, is commonly called "the gain peak" of the active region. It is also usually a relatively narrow peak, although somewhat broader than the cavity peak. In most VCSELs, the best active regions comprise one or more Quantum Wells ("QWs"), separated by barrier layers.

The gist of the '894 patent is how to compose active region QWs and barriers, whose gain peaks match the cavity peaks, at "extended" wavelengths in the vicinity of 1.3 μm, in VCSELs formed on GaAs substrates. This is illustrated in Figure (1)

attached. In the case of Multiple Quantum Well ("MQW") active regions, the implied assumption, since they do not address the possibility of different QWs in the same laser, is that the cumulative gain peak is an exact superposition of the gain peaks for all the QWs, since they are the same.

In most Edge-Emitting Lasers ("EELs") lasing occurs essentially at the maximum of the gain peak, as is shown in Figure (2) attached. In the case of such EELs with MQW active regions, the desired condition is where the cumulative gain peak is an exact superposition of the gain peaks of the individual QWs to maximize the height of the cumulative gain peak. The '130 patent addresses the possibility that in EELs there may be a temperature gradient between the QWs. Thus, if the heat sink (usually underneath the laser) of an EEL is at a temperature T_{hs}, the nearest QW will be at a temperature $T_{hs} + \Delta_1$, the next QW will be at $T_{hs} + \Delta_2$, the third QW will be at $T_{hs} + \Delta_3$, etc. Since gain peaks move to longer wavelengths as temperature increases, identical QWs in a MQW active region will not yield the desired exact superposition of gain peaks, that is, the gain peak of the lowermost QW will center at the shortest wavelength and the uppermost QW will center at the longest wavelength. The invention in the '130 patent is to make the QWs slightly different, so as to compensate for the temperature gradient, so that there again is an exact superposition of individual gain peaks. The '130 patent then teaches to calculate the wavelength shift for each Δ_i, and then to design the QWs so that, if they were all at the same temperature, T_{hs}, the gain peak of the uppermost QW would center at a wavelength appropriately shorter than the gain peak of the QW below it, and so forth, so that the gain peak of the lowermost QW would center at the longest wavelength.

S/No. 10/054,826

Unlike our application, The '130 patent does not address the issue of what happens as T_{hs} changes.

Further note, that in the '130 patent invention the QWs are in fact made not to act quasi-independently, but to have superimposing gain peaks, where none of the QWs dominates the cumulative gain peak. This is counter to the wording in our independent claims.

The main issue that our application addresses, and the '894 patent and the '130 patent do not address, is the fact that, in VCSELs, although both the cavity peak and the gain peak wavelengths change with temperature, at rates given in nm/°C, the gain peak changes at a much faster rate (about 5-6 times faster) than the cavity peak does. As a result, the gain peak moves relative to the cavity peak as a function of temperature. As is illustrated in the attached Figure (3), the net consequence is that the gain peak and the cavity peak may overlap over some temperature range, centered at T_{hs2}, but at, or below, a colder temperature T_{hs1}, and at, or above, a hotter temperature T_{hs3}, they no longer overlap sufficiently and lasing ceases. The typical temperature range of overlap may be no larger than a few 10's of degrees, depending on the actual width of the gain peak. If the active region comprises 2 or more identical QWs, and there is no temperature gradient between the QWs, their gain peaks superimpose and move together, as in the attached Figure (3). This arrangement does not improve the temperature range of operation, but can allow for greater net gain in the VCSEL (since the gain peaks add constructively) to overcome the need for some designed-in greater losses.

The subject matter described in our application addresses and ameliorates

the above problem of limited temperature range of operation in VCSELs. Neither the '894 patent nor the '130 patent address the issue of a limited temperature range for T_{hs}. The gist of our application will be reiterated below.

The essence of the solutions described in our application is composing an active region, which comprises two (2) or more QWs, separated by barrier layers, such that the gain peaks of the QWs are slightly staggered, or offset from each other, in wavelength, as is shown in the attached Figure (4) for the case of three (3) QWs, so as to produce a much broader cumulative gain peak. Then, as is shown in the attached Figure (5), as temperature changes, the cumulative gain peak sufficiently overlaps the cavity peak, over a much larger temperature range, including T_{hs1}, T_{hs2}, and T_{hs3}. The stagger occurs because the QWs act quasi-independently. The height of the cumulative gain peak is thus dominated by the height of the gain peak of the longest wavelength QW at low temperatures, by the height of the gain peak of the intermediate wavelength QW at intermediate temperatures, and by the height of the gain peak of the shortest wavelength QW at high temperatures. Note that in the case where a temperature gradient would exist between the QWs, as proposed in the '130 patent, the teachings in that patent would undo the effect our application proposes. In that case (of a temperature gradient), in our invention, the uppermost QW should actually be the one with the gain peak centered at the longest wavelength and the lowermost QW should actually be the one with the gain peak centered at the shortest wavelength. Thus the structure of the QWs in our application would not be the same as the one in the '130 patent.

Secondary claims in this application then describe the various ways the QWs

and/or barriers can be engineered to achieve the staggering of the gain peaks. Thereafter, the application also describes how these QWs and barriers can maintain a relatively constant gain over an extended temperature range, as is shown in attached Figure (5), since the cumulative gain peak is relatively flatter over a larger wavelength range than the individual gain peaks.

The '894 patent mentions the possibility of making the QWs in the active region of a VCSEL different. However, The '894 patent does not discuss the issue or the possibility of extending the temperature range of performance of any and/or of all VCSELs. The entire emphasis there is on extending the VCSEL wavelength, that is, on ways of making longer wavelength gain peaks, which will overlap with a cavity peak that is much longer in wavelength, in the vicinity of 1.3 μm, than those of previously made VCSELs. The '130 patent actually discusses how to undo the stagger in the gain peaks of a MQW active region produced by a temperature gradient and does not discuss how to increase the range of T_{hs} for any kind of lasers and in particular in the case of VCSELs.

It can thus be appreciated that the subject matter of our application would not be obvious over the '894 patent in view of the '130 patent because, not only is the necessary suggestion to combine the references missing, but the invention of our application provides a solution to the problem of decreased gain in a VCSEL as the temperature changes that neither the '894 patent or the '130 patent solve individually or combined. Furthermore, the art of designing EELs, as discussed in the '130 patent, is significantly different than the art of designing VCSELs, as discussed in the '894 patent, so as to make it impossible to classify the '130 patent as analogous art.

S/No. 10/054,826

Reconsideration and allowance of claims 1-28 is respectfully solicited.

Accordingly, claims 1-28 are believed to be in condition for allowance and the application ready for issue.

Corresponding action is respectfully solicited.

PTO is authorized to charge any additional fees incurred as a result of the filing hereof or credit any overpayment to our account #02-0900.

Respectfully submitted,

Joshua A. Stockwell
Reg. No. 54,580

BARLOW, JOSEPHS & HOLMES, Ltd.
101 Dyer Street
5th Floor
Providence, RI 02903
401-273-4446 (tel)
401-273-4447 (fax)
jas@barjos.com